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FOREIGN TECHNOLOGY DIVISION

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AERONAUTICAL KNOWLEDGE

(Selected Articles)

FOREIGN TECHNOLOGY DIVISION

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THE FLIGHT TOWARDS THE PACIFIC OCEAN - EYEWITNESS RECORD OF CHINA'S CARRIER ROCKET LAUNCH TEST

It was daybreak and there was a tense atmosphere in the area of the rocket launching site. The launch test of a carrier rocket which people had long looked forward to was about to begin.

The high launching tower encircled the milk white large-scale carrier rocket and towered over the launching site. Each of the special engineering technicians having carried out final pre-takeoff checks and operations on the rocket had left the site and were filled with intense emotion as they waited for the launch.

In the underground launch control room, commanders had their eyes fixed on the electronic clock and were listening to each word of each operations report and then made their respective decisions. The words of command came: "ten minutes, ready" ..... "five minutes, ready" ....."one minute, ready" ..... As the final few seconds arrived the various tracking and measuring equipment, high speed cameras, magnetic tape recorders etc. were all switched on.

"Ignition" the order came down. A young operator on the launching control tower pressed the button down decisively. Immediately there was a continuous tremendous roar transmitted at the rocket launching site. This sound was like that of a landslide, a seismic sea wave or an earthquake. The tremendous rocket lifted off from the earth and rose slowly, its tail blowing brilliant flames as it went straight up into the cloudy sky.

The launch is a success! people shouted as they gazed at the fiery dragon soaring into the sky, their hearts surging with emotion like the tossing of ocean waves.

How many days and nights did the numberless pioneers struggle to develop it on the national defense scientific research front and how much arduous labor was expended for this large-scale carrier rocket.

The rocket soared straight up into the blue sky. After several seconds, the vertically ascending rocket began to turn. After several tens of seconds, the gas emitting from the rocket congealed into smoke just like a strip of white silk stretching out into the vast sky towards the southeast; on the vast horizon it finally slowly changed into a small spot penetrating through the atmospheric layer vanishing from our field of vision.

However, from China to the oceangoing surveying fleet, several hundred sets of Chinese designed and made modernized

surveying and communications equipment firmly "gripped" the small light spot invisible to the naked eye and accurately measured, recorded and reported the flight speed altitude and position of the rocket each moment. Each second there was a large volume of measurement data which was collected from far and near and sent to the measurement control data exchange center. The measurement control center uses the various precision instruments and lines and joins all of the participating test units into a close struggling collective. The data is quickly collected and exchanged among each participating unit and they continually report the rocket's flight data to each measurement station so that each station can accurately track the rocket. Moreover, the information measured by each station and the rocket's flight condition are promptly transmitted to the computer control center and command center. Good news was transmitted continually: "Tracking excellent!", "Functioning normal!", "Flight normal!".

On each line of the television screen in the flight control center multicolored numbers alternated repeatedly and the automatic recorder lightly traced the curve of the rocket's flight path on the display panel. This line tallied closely with the advance target's theoretical ballistic curve and its shape told everyone that the instruments inside the rocket were operating normally and that its flight was normal.

After the rocket flew for a long stretch of time, it once

again entered the atmospheric layer and flew straight to the predetermined area in the Pacific. All was normal and the flight was as successful as was hoped for. Everyone was visibly pleased.

The waves in the Pacific were clear and bright. Fluttering in the wind were the five-star red flags on the surveying ships and salvage boat, just like an honor guard welcoming soldiers, lined up neatly on the two sides of the rocket's predetermined drop area. A destroyer was patrolling around the fleet. Each of the telemetering helicopters flew into the blue sky to coordinate with the various measuring equipment on the surveying ships so as to catch its path.

The rocket flew into the predetermined shallow ocean drop area at a high speed.

"Target found!". The people crowded on the deck in succession looking with fixed eyes northwest of the fleet. Soon thereafter, a bright spot came out of the cloud layer in a dazzling white light and flew straight to the predetermined ocean area. The bright spot became larger and larger and when it was still several thousand meters above the ocean surface, the instrument capsule with the important flight parameters installed in the rocket was automatically ejected from the rocket's nose. A parachute opened and the capsule slowly floated down on to the ocean surface. The rocket nose then entered the ocean with a splash causing a water column which shot up into the air. When

the instrument capsule fell into the water, the fluorescent dye dyed the blue sea water an emerald green color, like a bright and colorful strip of a several hundred meter long brocaded belt floating on the ocean surface.

At this time, the fast work vessels which had been waiting in the vicinity began to approach the drop area like arrows leaving a bow. My salvage helicopter quickly flew towards the drop point. When the helicopter arrived just over the instrument capsule it hovered 30 meters above the ocean surface. A diver followed the hanging ladder down and jumped into the ocean. In only five minutes and 20 seconds the capsule was triumphantly fished out. The helicopter carrying the instrument capsule flew safely to the flight deck of the salvage boat.

Announcement of the New China Agency

New China Agency, Peking, May 9. Authorized announcement of the New China Agency: From May 12 to June 10, 1980, the People's Republic of China will carry out a carrier rocket launch test from China to the Pacific Ocean with its center being 7 degrees 0 minutes south latitude and 171 degrees 33 minutes east longitude with a 70 nautical mile circular range. Chinese vessels and aircraft will operate in the area. In order for the vessels and aircraft to come and go safely, the Chinese government requests that related governments be notified of China's vessels and aircraft and not enter the aforementioned sea area or air

space above that area.

New China Agency, Peking, May 21. A news announcement that China's launch test of a carrier rocket from China to the Pacific Ocean during the May 18 to May 21, 1980 period was completely successful.

This is an important achievement gained from China's building of socialist modernization and is the result of self reliance, the revolutionary spirit of arduous struggle, the liberated ideology, the painstaking intensive study, the hard work and energetic cooperation of all of the participating research and development, production and test scientific workers, engineering technicians, workers, officers and men of the People's Liberation Army and other related personnel.

The Party Central Committee, State Council and Military Commission of the Central Committee of the Chinese Communist Party extend their enthusiastic congratulations to them.

THE WHOLE TEST COURSE OF THE CARRIER ROCKET

by Wu Yongshu

On the morning of May 18, in a clear and boundless sky, there was a tremendous thunderous sound at a certain launching site in China and a large scale carrier rocket rose into the sky, charged through the clouds and streaked across the sky straight towards the South Pacific Ocean. After several tens of minutes of outer space flight it returned into the atmosphere and fell accurately into the predetermined ocean drop area, thus successfully completing China's first flight test of a large scale carrier rocket. The success of the test signified that China's carrier rocket technology had entered a new stage.

The success of this large scale rocket flight test also greatly inspired the faith of China's people in the self reliant struggle to carry out the four modernizations. At the same time, it also caught the interest of aviation enthusiasts towards carrier rocket flight tests. This article only presents the following four questions as a simple introduction:

1. Why is it Necessary to Carry Out Flight Tests for Carrier Rockets?

If a rocket is used to send a satellite or spacecraft into a predetermined orbit to survey the universe, this is called a spacecraft carrier rocket; if it is used to transport a warhead carrying a nuclear charge over a long distance to destroy an enemy target, then it is called a ballistic missile. Generally speaking, a carrier rocket is able to send a satellite into a low trajectory of about 300 kilometers and can also project a missile of equivalent weight to a target area over 8000 kilometers away. The common ballistic missile with a range of over 8000 kilometers is the intercontinental ballistic missile. It can be seen from this that the carrier rocket and intercontinental missile were originally a pair of twin brothers, only the quality of their effective loads and the uses assigned to them are different. Aside from this, in design, development and test method, the spacecraft carrier rocket and intercontinental missile have many points of similarity. Therefore, in reality, the launch test of a spacecraft carrier rocket is often carried out in conjunction with the flight test for the intercontinental missile.

Flight tests are indispensable key links in the development of rockets and missiles and are also the final stage for advancing their development. We know that the development of any new product always requires a large number of tests but the more complex the product, the more arduous the testing and the more varied the procedure. Large scale carrier rockets or intercontinental

missiles are very complex systems which include the power equipment, control system and rocket structure and as many as ten thousand parts. To guarantee that these complex systems operate in coordination with each other and reliably, as well as be able to hit a target (or enter a trajectory) accurately according to a predetermined ballistic flight, it is necessary to carry out a large number of repeated tests.

Tests of carrier rockets are commonly divided into ground tests and flight tests. So-called ground tests utilize various laboratories, test platforms and simulators on the ground to carry out various types of structural performance tests, environmental simulation tests and power tests on the parts of each system such as cold and hot test runs for the engines, wind tunnel tests outside the aerodynamic structure as well as various environmental tests such as for shock, vibration and noise. Flight tests are carried out on the basis of large numbers of ground tests and are divided into partial range flight tests and whole course flight tests. Partial flight tests basically test the operating reliability of each separate system and the level of maturity of each item of technology (such as an engine's high altitude ignition, the stage separation of multistage carrier rockets). Whole course flight tests are carried out on the basis of each separate system and the maturity of each item of technology. Briefly, the so-called "whole course" is the carrier power needed by the rocket to be able to reach the actual range

of fire and a whole course flight test examines the nearest actual flight environment provided for the aircraft. It tests the operating reliability of the aircraft's entire system and the coordination among each of the separate systems; comprehensively examines the technical fighting performance of the aircraft, especially the guidance precision (or target hitting precision) and the heat prevention ability of the re-entry body when returning into the atmosphere.

Because the carrier rocket's system is complex, its manufacturing costs are high and it is a product which can only be used once, during development there are a large number of ground tests. However, for flight tests, especially whole course flight tests, there are many limitations, yet they are absolutely necessary.

2. How are Flight Tests for Carrier Rockets Organized?

The whole firing range of large scale carrier rockets are generally greater than 8000 to 10,000 kilometers. Because the national borders of various nations are limited there is no way of utilizing inland territory for whole course tests. Only the ocean area occupying 71% of the earth's surface can be used for flight paths. Therefore, launched from the initial launching site and extending the navigation area and drop area to the ocean is an effective method of carrying out a carrier rocket whole course test. Both the United States and the Soviet Union

use the Atlantic and Pacific Oceans to carry out whole course flight tests for carrier rockets and intercontinental missiles. China selected the ocean water area of the South Pacific as the test drop area for the carrier rocket.

Ocean tests cause the sea operations of drop area tracking and surveying, retrieval of the data capsule, ocean communications command and ocean logistics supply to be carried out. These present many new problems for the preparatory tasks of flight tests. Before the United States and the Soviet Union carry out whole course flight tests, they first select an ocean drop area, examine the hydrological, meteorological and geological characteristics of the waters in the area, develop high precision tracking and surveying equipment and carry out maritime tracking and surveying with reequipped and newly built large scale surveying ships and aircraft which possess various surveying methods for carrying out ocean communications tests. Aside from this, during the flight test , the afterburn of each stage of the rocket and the flight's breakdown both carry possible safety and danger and thus it is necessary to have highly reliable safety remote control equipment and safety measures.

Furthermore, because ocean tests are related to intercontinental aviation and navigation work, it is necessary to publicly announce the test date and ocean area on the eve of the test. It is necessary for the surveying and salvage recovery boats to be bound for the predetermined ocean area and to prepare the sea

operations in advance. The initial launching site and drop area survey ships begin launching sounding rockets and utilize meteorological radar for meteorological surveyance. Meteorlogical predictions are issued so as to select the best weather for launching. The range communications system must guarantee the coordination of several hundred pieces of surveying and communications equipment in an over 10,000 kilometer path between the initial and drop areas. This is all pre-test preparatory work. It is clear that a whole course flight test of a large scale carrier rocket is a large scale test process with a long preparation period, strict organizational command and complex technological coordination which involves many of the most advanced areas and systems of science and technology. Therefore, the success of a whole course flight test of a large scale carrier rocket reflects the scientific and technological level of a country.

3. The Flight Test Site and Measures

The site of the flight test is composed of three parts: the initial launching site, the navigation area and the drop area. The launching site is usually located in one's native country and most navigation and drop areas are at sea. The drop area is specially established on an ocean surface far from one's native country.

The initial launching site is usually called the missile and

space range site or missile space launching site. It is the indispensable large scale comprehensive test installation in the process of missile development and the launching of spacecrafts. During flight tests, from this point a large scale carrier rocket or missile takes off, travels into space and begins the first step of its 10,000 kilometer journey. The launching of a carrier rocket is the key to a successful test flight for if the launch is poor a successful flight is impossible. As soon as one enters the launching site, what first greets you is the high imposing service tower. It does the pre-launch hoisting, assembling and holding of the "expedition" rocket and carries out various pre-launch tests and safeguards for the hoisting or holding of a rocket on the launching pad; the launching pad is the accurate positional firing direction provided for the rocket; the propellant and high pressure gas storage warehouse use the filler pipeline to carry out pre-launch filling; the igloo-shaped underground control room is used for pre-launch preparatory monitoring and uses the rocket-firing automatic program system for launch ignition.

Aside from this, there is also a command control center, communications center, meteorological facilities, time unity service facilities and data processing center for the distant launch position as well as various types of photographic and radio surveying equipment for tracking and surveying.

The command control center implements unified commands,

control and coordination for the whole site area's testing operations, tracking and surveying facilities as well as each participating testing department. The command center has a command control tower as well as various display equipment. Its large display screen demarcates the rocket's theoretical ballistic path, the flight test time and the rocket's instantaneous position, speed and attitude data. This data is sent here from each measuring system through several transmission lines and is thus able to draw the actual flight path. Moreover, it is compared with the theoretical trajectory so that commanders in charge of site area safety can determine trouble and so provide a basis for safety control.

The task of the communications center is to ensure the communications link along the over 10,000 kilometer path between the launching site and drop area surveying ships; to guarantee the coordinated action of the several hundred pieces of tracking and surveying equipment; to complete various command, control, coordinated instruction and meteorological , time unity and surveying data transmission.

Range test communications use wired high frequency radio and microwave communications and after satellites were put into use satellite communications were also used in range flight tests.

The time unity center provides a unified time basis for each surveying system during the flight test.

The navigation and drop areas. The flight navigation area is also called the rocket's flight corridor. In order to carry out continuous tracking and surveying of the rocket's flight condition, it is necessary to set up a fixed number of tracking and surveying stations in the navigation area. The initial launching site of the United States is set up along its own southwest coast and they use tracking stations set up on islands along the coast to complete ocean surveying. Most of the Soviet Union's navigation area for whole course carrier rocket flight tests is in the sky above its own land and therefore there are land tracking stations set up throughout that country.

The drop area is also called the target area. During a whole course flight test, survey ships and salvage recovery ships must carry out ocean operations here, survey the entry body and recover the data capsule. Therefore, the selection of the drop area, besides needing to satisfy test range requirements, must also consider the environmental conditions of the ocean operations, avoid typhoon areas, avoid major navigation lines and islands with concentrated populations as well as seek good weather conditions.

4. Flight Test Tracking and Its Equipment

The flight path of a large scale carrier rocket is divided into three stages according to the special characteristics of its trajectory path; the initial stage (also called the power

flight stage), the free path flight stage and re-entry stage.

Flight test tracking and surveying can be divided into two categories according to its different surveying tasks. The first category is the surveying of the rocket's movement conditions and the other category is surveying the movement conditions of the rocket's internal operating conditions including the recording of each engineering task during high speed flight (for example, the stage separation and re-entry into the atmosphere of a multi-stage rocket) as well as surveying the rocket's position, speed and attitude. The surveying of the rocket's movement parameters is called external ballistic surveying. The changes of the rocket's flight conditions are closely related to the operating condition of each of its internal systems. The changes of the rocket's movement condition reflects the working conditions inside the rocket and the environmental influence outside the rocket. Radio telemetering is an important method for monitoring and surveying the operating conditions inside the rocket. Radio telemetering equipment includes the two parts of sensers and emitters, and ground receivers. The first step of the telemetering process is the surveying of the non-electric physical quantity on the spacecraft such as the pressure, temperature and propellant's discharge in the engine combustion chamber. After passing through the senser it transforms into a voltage signal and after modulation an emitter is used to transmit the high frequency electric wave to the ground. It is

received by a ground high gain antenna and after demodulation the telemetered signal is separated and given real time recording. Following the development of space technology and ballistic missiles, telemetering parameters have advanced from the original several tens of paths to several hundred paths.

Among the equipment used to survey the external trajectory of a rocket, there are photographic survey equipment and radio survey equipment. Photographic survey equipment is mainly used for surveying external trajectory during the initial stage and re-entry stage wherein the rocket's flight path is accurately and directly photographed. It includes tracking observation equipment and photographic equipment. Tracking observation equipment is a type of camera which can track movement. Its lens changes with the position changes of the rocket in space. The lens does not follow the movements but is a stable piece of photographic equipment. The use of two or three pieces of photographic equipment can survey the position of a fixed target in space. Naturally, they can also add a laser range finder to a single station for target orientation. When carrying out film transit work, a fixed frequency is used to simultaneously photograph the target positions and the shooting lens makes the graduation of the tracking movement's angle of site and azimuth. When carrying out ballistic camera work, celestial bodies are used as a reference system so that the rocket's flight path and fixed stars are photographed simultaneously on

a sensitive plate. After being compared to the fixed stars, an accurate position can be attained.

Radio external trajectory survey equipment is an important means of surveying during flight tests. It possesses the ability of long distance capturing and tracking targets, and can operate in all types of weather. Yet, when carrying out low elevation tracking, it is easily affected by miscellaneous ground wave interference. Therefore, radio equipment and photographic survey equipment complement each other and form an indispensable part in external trajectory surveying. The positioning principle of radio survey equipment is the transmission of electromagnetic waves and the use of a target's reflection characteristics for the electric waves and the known electric wave transmission speed to survey the target distance; the use of the vertical and horizontal axes angle of rotation transmitted around the electromagnetic wave antenna to determine the azimuth and angle of site, that is, to determine the rocket's position. At present, commonly used radio survey systems have single pulse radar and continuous wave systems.

Aside from this, other laser, infrared and sonar survey equipment are also used in flight tests which together form land tracking stations and ocean mobile stations — range survey (survey aircraft). Furthermore, they track and survey high speed carrier rockets from take-off to landing.

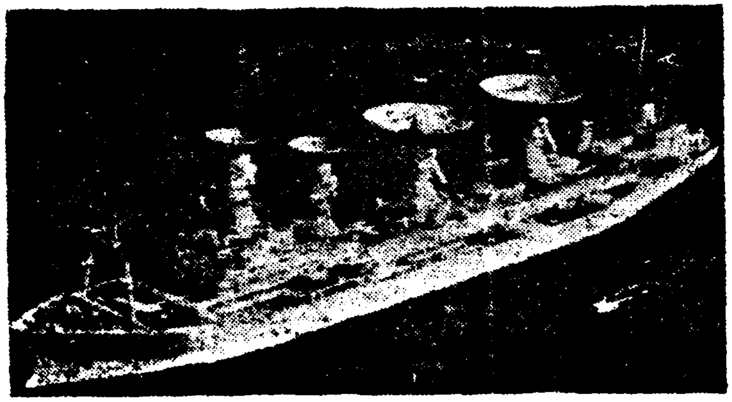

Fig. 1 A Foreign Survey Ship Used to Survey Missile Re-Entry Trajectory and for Tracking Spacecraft

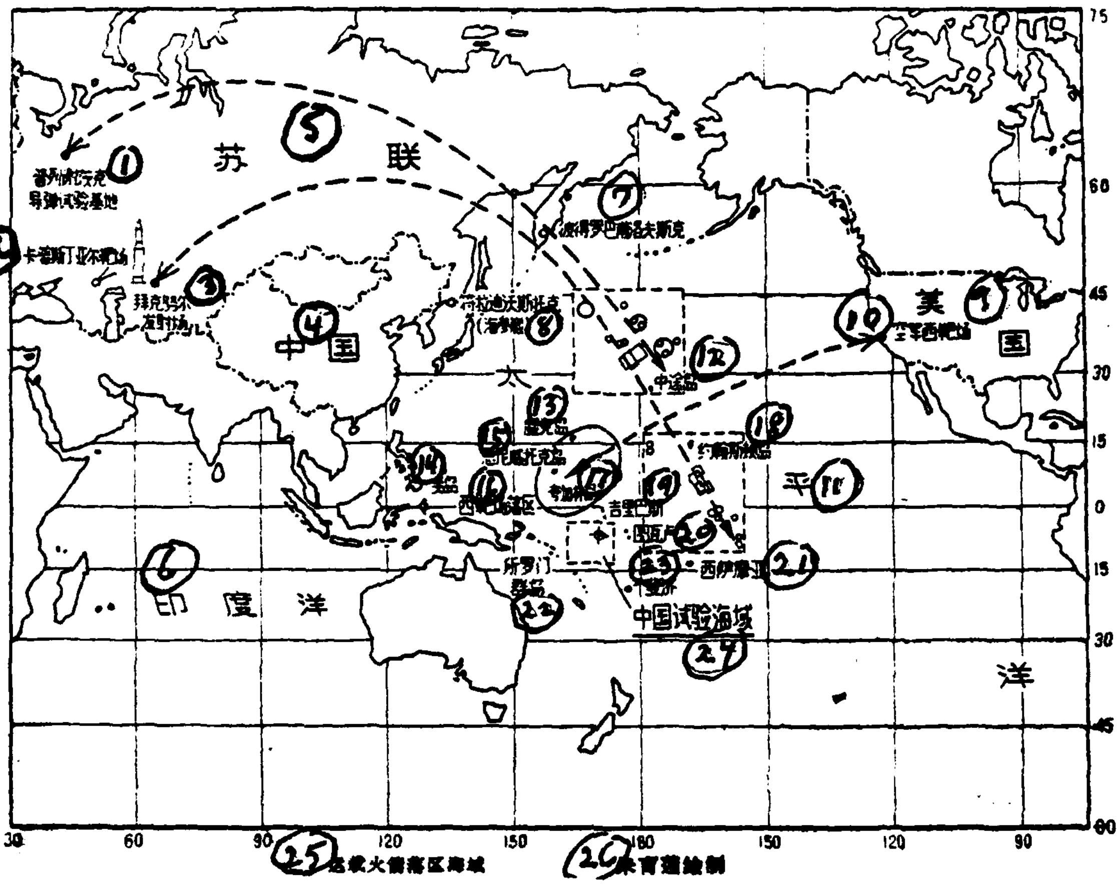

Fig. 2

Key:

1. Pulixiecike Missile Test Base
2. Kapuzidingyaer Range
3. Baikenuer Range
4. China
5. Soviet Union
6. Indian Ocean
7. Petropavlovskiy
8. Vladivostok
9. United States
10. Western range of the airforce
11. Pacific Ocean
12. Midway Islands

13. Wake Island
14. Guam
15. Eniwetok Island
16. Western range drop area
17. Kwajalein Island
18. Johnston Island
19. Gilbert Island
20. Tokelau
21. Western Somoa
22. Solomon Islands
23. Fiji
24. China's ocean test area
25. Carrier rocket ocean drop area
26. Drawing by Zhu Julian

Title and picture design: Li Jia

SATELLITE AND CARRIER ROCKET SEPARATION

by Qi Deng

[Preface]

When we consider the task of accurately sending a satellite into a predetermined space orbit, each component of the carrier rocket must be reliable. Moreover, the separation of the satellite and carrier rocket is an important and indispensable factor in this work.

[Text]

Satellites use a release mechanism to connect on to the carrier rocket so that after the last stage of the carrier rocket is finished, the satellite separates from the last stage in accordance with a predetermined program and enters a predetermined orbit.

To judge whether or not a satellite launch is successful is to mainly observe whether it entered orbit as well as whether each system is operating normally after entering orbit.

Included in this, it is very important whether the satellite can maintain orientation as the quality of the separation of carrier rocket and satellite directly affects is orientation. Following the lengthening of satellite life and the demands for orbit entering precision as well as increases in weight, designers have been more concerned with having separations without interference so as to satisfy the demands for satellite orientation.

Further, the problems of separation blast and explosive rope (or explosive bolt), pollution during rocket reverse thrust and fragments flying because of explosion, cannot be overlooked in separation design. Below we will discuss how a satellite separates.

Separation After First Providing Orientation

Satellites usually use non-fragmenting explosive bolts or explosive rope locked securely on the last stage of the carrier rocket. Prior to separation, the attitude control system of the last stage of the rocket adjusts the combined last stage and satellite to a suitable attitude. For example, the satellite's antenna, probe or reconnaissance equipment are aimed toward the earth and this provides orientation for the satellite. Afterwards, the program installations issue separation commands according to a predetermined program thus detonating the explosive bolt and allowing the satellite and last stage to

unlock. Moreover, the firing of the separation spring or small solid reverse thrust rocket produces separation force which separates the satellite and last stage. After separation, the satellite continuously moves along the orbit.

Why is it necessary to first provide the satellite orientation? Originally earlier small scale satellites did not have attitude control systems but completely relied on the last stage before separation for orientation. Later, they relied on the satellite's own rotation or the gradient of the earth's gravitational force to maintain this kind of orientation. Although large scale satellites have their own attitude control systems yet the weight of the fuel which produces the control force is strictly limited. When the last stage of the rocket first provides orientation for the satellite, this can save a portion of the fuel used for attitude control and thus can extend the orbital life of the satellite. However, this must guarantee that the interference during the last stage-satellite separation is very small, otherwise all previous efforts will have been wasted. Taking the "nimbus" meteorological satellite as an example, if the interference angle speed during separation is greater than 0.1 degrees per second, then the satellite's attitude control system must revise the deviation caused by the interference and its consumed fuel can exceed the stipulated quantity. Therefore, it is necessary to guarantee that the separation's interference is very small and to satisfy the orientation precision demands it is necessary to select an

appropriate separation system.

The Ejection and Deceleration Separation Systems

At present, many different separation devices are used for separating satellites. These devices can basically be divided into two categories: one category is the forward ejection of the satellite from the last stage of the rocket which is an ejection separation system; the other category is the deceleration separation system wherein several small solid reverse thrust rockets or gas cooled nozzles are installed in the last stage to produce reverse thrust with the movement direction of the carrier rocket so as to decelerate the last stage (fig. 1). Further, after the satellite and last stage break away the satellite relies on inertial flight.

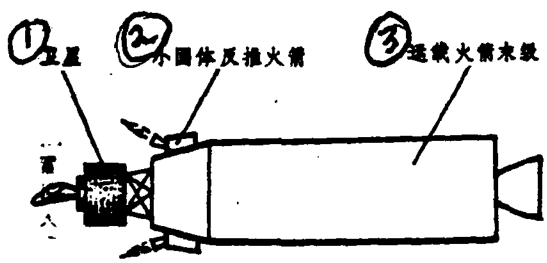

Fig. 1 Diagram of Small Solid Reverse Thrust Rockets Used for Deceleration Separation

Key: 1. Satellite
2. Small solid reverse thrust rocket
3. Last stage of carrier rocket

Reverse thrust rockets can be installed on the tail section or leading end of the last stage. Its nozzle requires a small

angle deviating outward so that the blown gas will not erode the satellite. Otherwise, the gas can blacken the lenses of the photographic equipment with smoke and seriously affect the operations of the satellite such as the temperature control layer and the solar energy cell on the satellite's surface.

Because the reverse thrust force of the reverse thrust rocket acts on the last stage and not the satellite, the deviation and the ignition of the reverse thrust rocket's thrust which are non-synchronous as well as the unbalanced moment caused by the installed deviation basically eliminate the interference of the satellite.

The ejection separation device can use a pneumatic, spring or powder ejection tube. Among these, the spring type is the most commonly used. The simplest and least expensive satellite separation method is the use of a single compressed spring which is installed on the common axis of the last stage and satellite and releases separation energy. When greater spring separating force is needed, several springs joined together can be used and the level end of each spring is symmetrically fitted on the bottom end of the satellite (fig. 2).

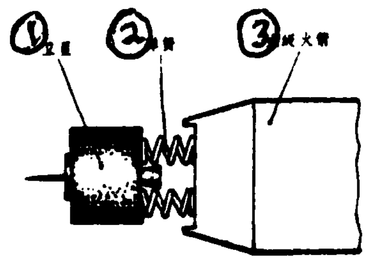

Fig. 2

Fig. 2 Diagram of Ejection Separation Using Springs

Key: 1. Satellite
2. Spring
3. Last stage of rocket

Each spring produces a moment for the satellite and therefore it is necessary to consider the deviation of the spring force and the elimination of the unbalanced moment. This requires relatively accurate throw for each spring or the careful selection of more springs.

The gas cooled (such as nitrogen) jet separation system is composed of a gas bottle, burst valves and a spray nozzle directly connected to the gas bottle. Its outstanding feature is that it sprays gas cleanly, yet nitrogen is much better than small solid reverse thrust rockets.

In general, spring and gas cooled separation are most often used for satellites in which the separation energy demands are small and solid reverse thrust rockets are used for satellites with large separation energy demands.

Separation Cleanliness and Neatness

Among the requirements for many separations one very important item is preventing the possible pollution of a burned out solid engine on the satellite. Usually, the small solid engine has an inner bushing of non-metallic heat insulation and a housing bound by glass silk epoxy resin. After the solid rocket engine burns out, the temperature in the combustion

chamber generally rises continuously. For example, when the satellite is still connected on the distant point of a solid engine, the temperature in the combustion chamber rises causing the epoxy resin to volatize and the volatized gas pollutes the satellite.

Furthermore, it is also necessary to prevent the residual thrust of the separated solid engine from accelerating the engine. What is residual thrust? Residual thrust is the thrust produced from the nozzle exhaust and the continuous combustion of the not yet burned up solid propellant after the engine has burned out. If the relative distance between the engine and satellite separation is not large enough, it is possible that the solid engine accelerated by the residual thrust will catch up to the satellite in front and cause a collision. The main liquid fuel engine on the last stage also has residual thrust after burning out. It is produced by the thrust chamber nozzle cooling in the sleeve and the evaporation of the remaining propellant in the tube after the main valve is closed. To avoid a collision with the satellite, a side force can be added on the last stage so as to cause the last stage to have deviated flight and separate far from the satellite.

Earth synchronous orbit satellites are fitted with apogee solid engines so that the final accelerated satellite will enter an earth synchronous orbit. Naturally, after entering orbit, this used up engine is still connected to the satellite and

can lower the efficiency of the satellite's attitude control.

In space, the pressure of solar electromagnetic radiation (also called light pressure) can push the satellite in an elliptical orbit outside the orbit and thus influence the completion of the satellite's mission. To decrease the effective area of the solar light pressure it is necessary to separate off the used up solid engine.

The best time for satellite separation is after the last stage engine burns out from the time the thrust decreases until it reaches zero. Yet, there are exceptions. For example, at times a satellite's antenna and solar energy cell surface must first be opened up; some separations require monitoring by the ground station. In this way, the satellite and last stage of the rocket must have a section of continuous connected flight until it enters the working area of the ground radar station.

The Separation of Multiple Satellites

Can we use a rocket to launch several satellites? Yes. This only requires multiple satellite separation. The method is to firmly lock together each of the satellites on a satellite mount (see fig. 3).

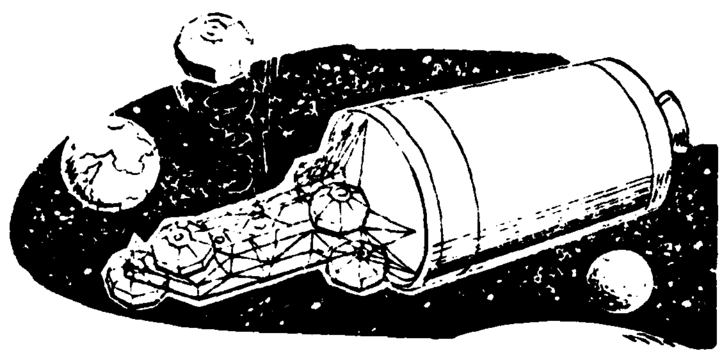

Fig. 3

After using the last stage of the rocket to first give orientation to the satellite, the first satellite is separately fired from the mount at orbital speed. After each satellite is ejected, axial gas is sprayed from the attitude control system of the last stage of the rocket. This provides a small acceleration so that the next satellite attains added orbital speed and thus the satellites are distributed along the orbit. If larger separation force is required, it is only necessary to use a higher powder than the spring efficiency or a small solid rocket wherein the weight of the powder ejection tube has a higher reliability than the spring separation system but produces a greater blast. The blast caused by separation of the satellite includes the total bending oscillation of the spacecraft's structure and the local structural response. The

total response is of no consequence to the structural strength but the local response can cause relay oscillation. It can sometimes bring about the premature production of some commands and can also have a destructive effect on many small electronic components thus causing flight failure. Yet, it is only necessary to use oscillation decreasing measures and equipment for ground oscillation tests. This problem is not difficult to resolve.

In general, the separation of satellites requires the comprehensive consideration of the problems of required separation energy, the weight of the system, the blast, control and pollution. To satisfy even higher present and future demands, spring and gas cooling separation methods are in the process of being replaced by small solid rocket and non-polluting explosive rope release and locking separation systems.

Fig. 4 Environmental Satellite in Earth Synchronous Orbit